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A Laboratory Study of Soil Reactions on Disks

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A Laboratory Study of Soil Reactions on Disks

Data dealing with the soil reactions on disks are limited as nearly all investigational work reported covers field operation of the disk harrow. For example, Stirniman (1) reported a series of tests of field implements which included draft tests on several disk harrow units, McKibben (2) developed an analysis of the soil reaction on disk harrows and off-set disk harrows and Sjogren (3) has worked out the main considerations in off-set disk harrow design. However, Clyde (4) has made tests of individual disks under carefully controlled conditions. He found that the diameter of the disk, the angle at which it is set, and the moisture content of the soil have marked influence on the forces acting on the disk as it is pulled through the soil.

Due to the manifold sizes and shapes of disk blades, the almost numberless ways in which they may be mounted and set and the extreme variety of soils and soil conditions, the number of disk tests that may be made are infinite. In this study, the variables are limited

(1) Draft Tests of Farm Machinery. E. J. Stirniman, Amer. Soc. Agr. Engin. Trans. Vol. 12, 1931, pages 9-25

(2) Improvement of Disk Tools. A. W. Clyde, Agr. Engin. Vol. 20, No. 6, 1939.

(3) A Study of the Dynamics of the Disk Harrow. E. G. McKibben, Amer. Soc. Agr. Engin. Trans. Vol. 20, 1939, pages 113-126

(4) Development of Offset Disk Harrows. Agr. Engin. Vol. 17, No. 12, 1936.

for each series of tests in an effort to measure the effects of only one or two of the following factors; size of disk, concavity of disk, depth of working, soil type, soil condition, speed of operation, width of cut, bearing friction, angle with the line of travel and the angle of the disk with the vertical.

Description of Test Apparatus

The soil plots, the fitting equipment and methods of test and the dynamometer equipment have been described in detail heretofore (5). The unit in which the disk is mounted is shown in Figs. 1 and 2. When the disk test unit is coupled to the dynamometer of the power car, the disk then rests in a framework so constructed that the reaction of the soil on the disk is imparted to six hydraulic cells. These in turn actuate suitable pen elements, both in the dynamometer recorder and the disk unit recorder which record the ractions in a manner to permit a breakdown of the soil reaction on the disk into three directional components - the force required to pull the disk forward, the vertical component acting either upward or downward, and the side force acting either to the right or left. The soil reactions referred to in this report are net reactions and do not include the disk weight.

The following tabulations of the three components of soil reaction on the disk give the force required to pull the disk forward or draft in pounds per square inch of disk furrow slice cross section,

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(5) Tests of Tillage Tools. I. F. Reed, Agr. Engin. Vol. 18, No. 3, 1937

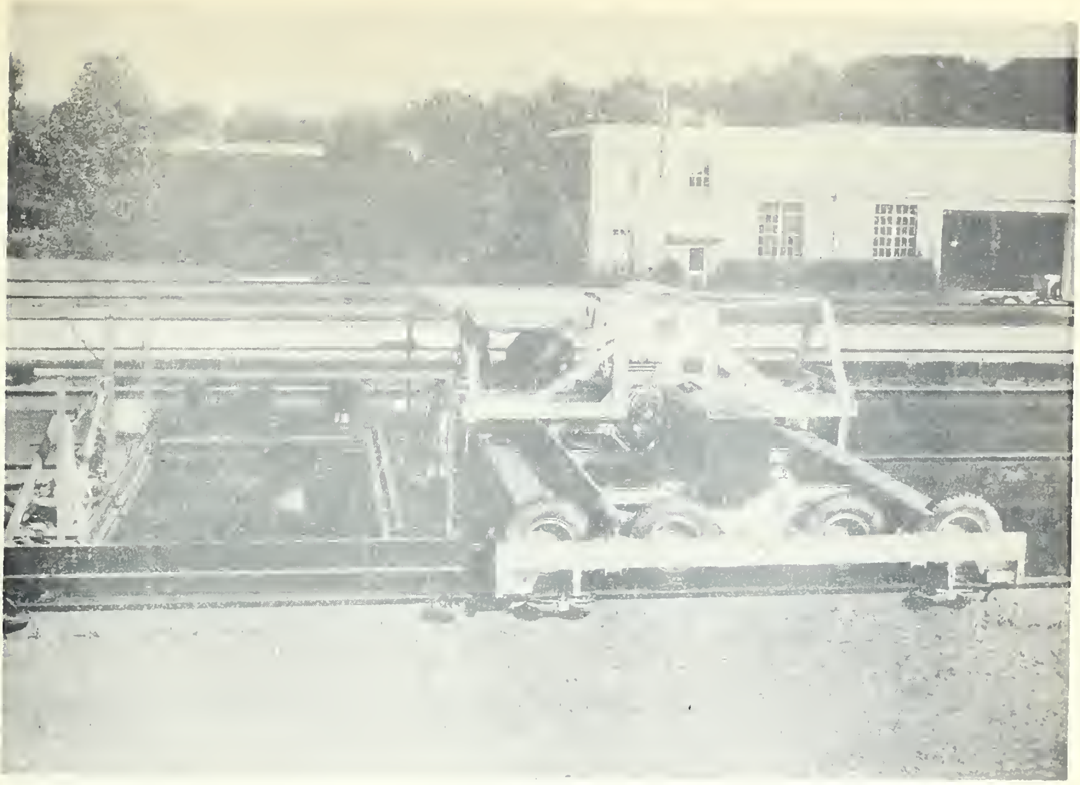

Fig. 1

The Disk Unit and Power Car Coupled in Position for Test Run.

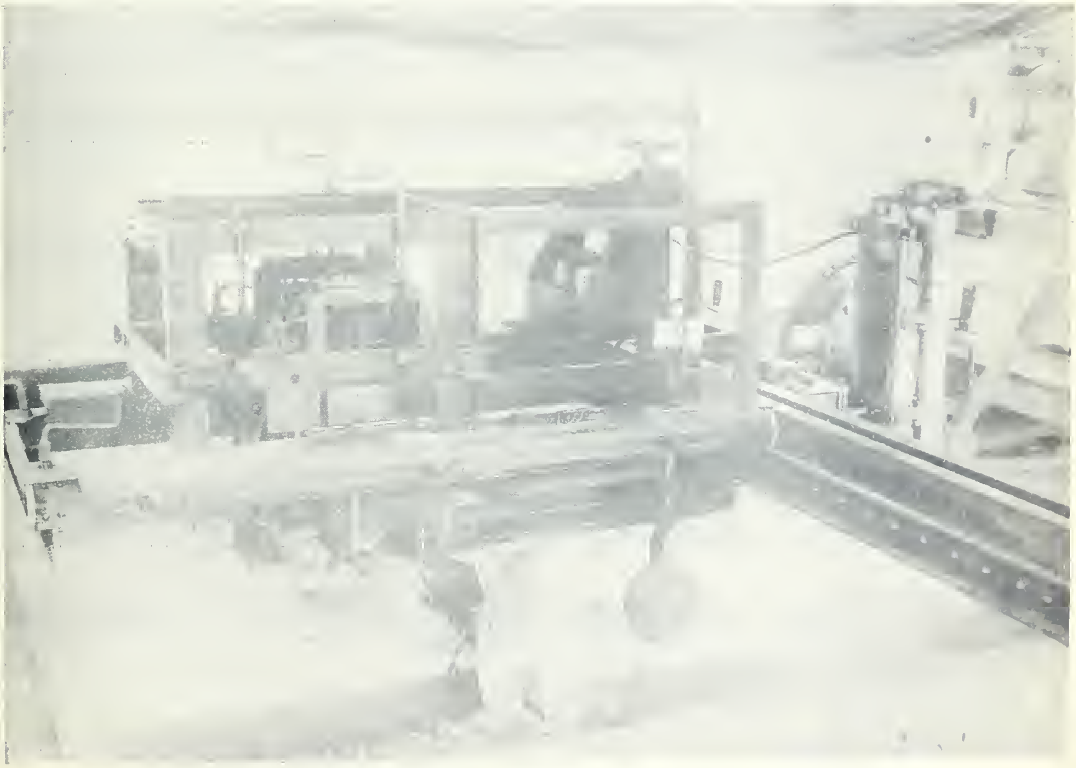

Fig. 2

Showing Arrangement of Pressure Cells and Disk Mounting.

the total vertical force upward or downward on the disk, and the total side force to the left of the disk. To gain a comparative idea of the relative power requirements for the different conditions of tests, the horsepower hours per acre are included in some of the tabulations.

Most of the tests herein discussed were made with disks having a nominal diameter of 26 inches. This is a comparatively large disk and was chosen because it is a size common to the vertical disk plow and the standard disk plow. In a vertical disk plow unit known variously as the Wheatland plow, one way plow, disk tiller or harrow plow, the disks are mounted in a vertical position as compared with the way in which the disk is inclined in a standard disk plow. (6)

Soil Reactions in Relation to Disk Angle and Angle of Inclination

The disk angle referred to is one which a plane parallel to the disk face makes with the line of travel. When the disk is inclined, the angle made by the plane of the disk with the vertical is called the angle of inclination.

In the operation of a disk harrow the disk angle adjustment is governed to a large extent by the amount of penetration. If the soil conditions are such that penetration is difficult, weight is added and the disk angle is made as great as possible for smooth operation. If the angle is too extreme, trouble would be experienced with gouging or "bucking" of the disk. If the angle is such that the convex side of the disk bears on the soil, it is obvious that the resistance to disk penetration would be considerably greater.

(6) Proposed A.S.A.E. Standard Disk Blades, Agr. Engin. Vol. 12, No. 1, 1931

In the mounting of the disk in a conventional vertical disk plow unit, the disks are mounted on an arbor and are spaced a uniform distance apart. For cover crop work, the disk spacing is usually 9 to 11 inches as contrasted with about 5 or 6 inches for the disk used in the western wheat sections.

An attempt has been made to measure the soil reactions on the vertical disk plow blade where the width of cut was equivalent to disk spacings of 8 inches, 10 inches, and 12 inches by using a single disk mounted in the test unit and observing the soil reactions at various widths of cut corresponding to a given spacing and disk angle. Table 1 shows the furrow width cut by each disk of a vertical disk plow unit with the various angle settings of the disk gang.

TABLE 1
Width of Cut in Relation to Disk Angle

Disk Spacing Inches	36°	41°	46°	51°
	Width of Cut - Inches			
8	6.5	6.0	5.6	5.0
10	8.1	7.6	7.0	6.3
12	9.8	9.1	8.4	7.6

From this Table it will be seen that for any common disk spacing, the greater the angle at which the disk is set, the narrower the cut will be.

In this study of disk angles the trend of soil reactions on a disk of 4-1/8-inch concavity is shown in Fig. 3 in the Norfolk Sand and Davidson Loam. This concavity is moderately deep and is the type of blade generally used on either a vertical disk plow or a standard

TABLE 2

Soil Reactions For Various Disk Angles

		Total			
Disk Angle Degrees	Unit Draft Lbs./Sq. In.	Vertical Force Downward Pounds	Side Force To Left Pounds	Power Requirements H.P. Hrs./Acre	Disk Concavity - 4-1/8" Radius of Curvature - 22-3/16" Speed - 2.2 mph Depth of Cut - 6" Width of Cut - corresponds to a disk spacing of 10".
					Soil Type - Norfolk Sand Soil Conditions Depth A.S.G.+ Moist.% 0-2 1.65 4.33 2-4 1.75 6.76 4-6 1.72 7.80
36	2.06	18	48	2.90	
42	1.70	45	33	2.46	
46	1.36	44	47	2.44	
51	1.66	48	25	2.61	
					Soil Type - Davidson Loam Soil Conditions Depth A.S.G.+ Moist.% 0-2 1.80 9.71 2-4 1.94 11.85 4-6 1.88 12.76
36	5.20	31*	136	7.33	
41	3.72	11	130	5.46	
46	3.68	65	101	5.52	
51	4.26	35	68	6.65	
					Soil Type - Decatur Clay Soil Conditions Depth A.S.G.+ Moist.% 0-2 1.43 10.66 2-4 1.52 14.50 4-6 1.56 17.42
41	7.20	137*	221	9.96	
46	7.28	168*	218	10.7	
51	8.75	154*	256	13.8	

* Indication that soil reaction is upward.
+ Apparent Specific Gravity.

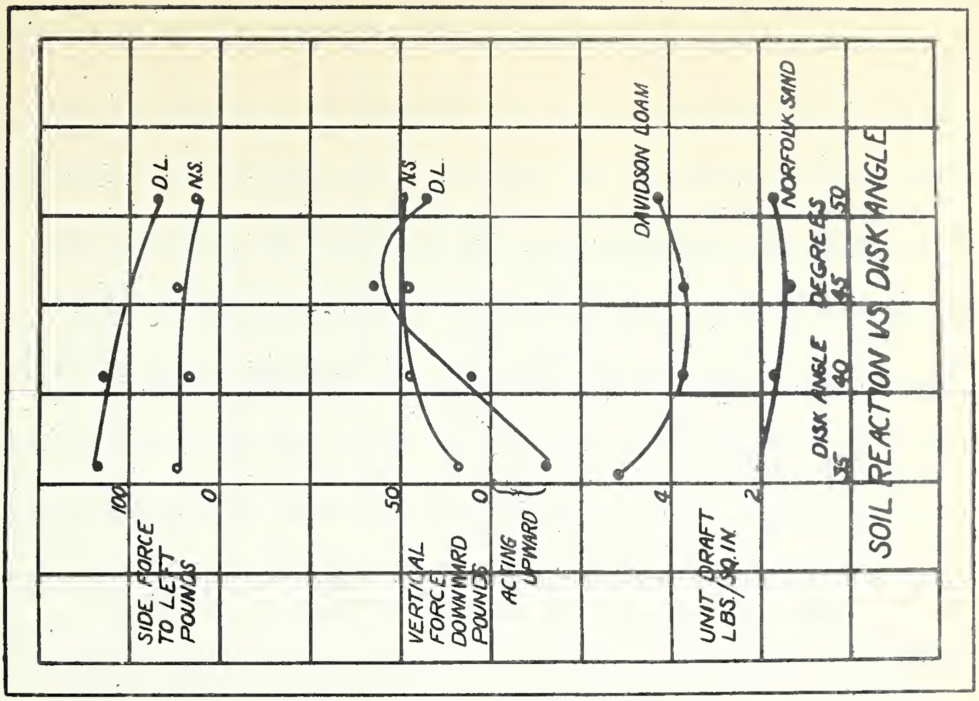

Fig. 3

Soil Reactions for Various Disk Angles
(Data plotted from Table 2).

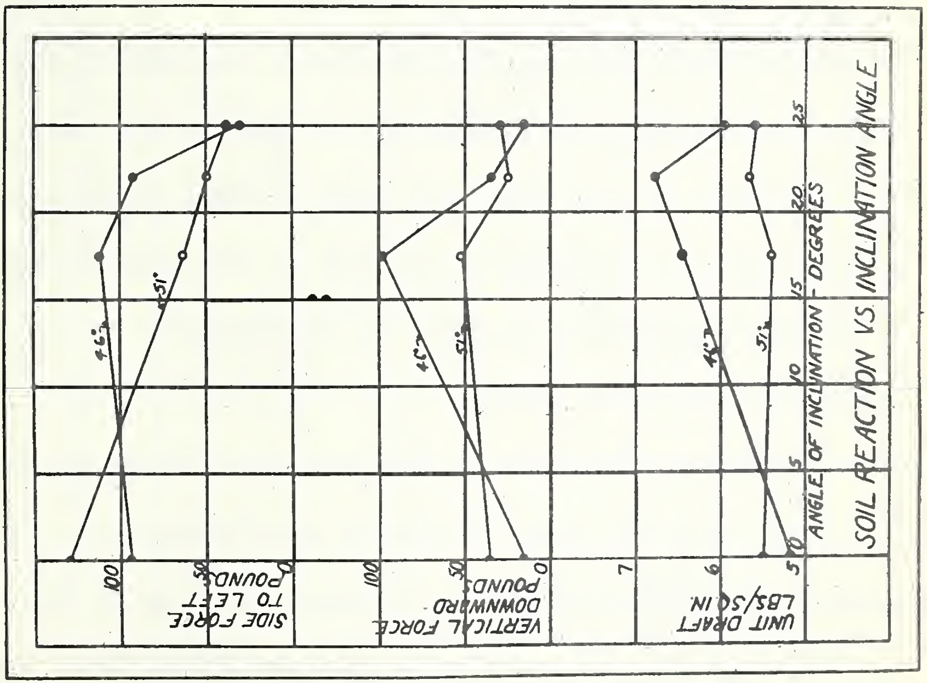

Fig. 4

Soil Reaction in Relation to Angle of Inclination
at Two Different Disk Angles.
(Data plotted from first section of Table 5)

disk plow. With this type of disk set at 36 degrees the soil reaction is upward in the Davidson Loam but changes to a downward component as the disk angle approaches 40 degrees. In the Norfolk Sand and the Davidson Loam, the vertical reaction downward is somewhat less at the 51-degree disk angle. The draft per square inch of furrow slice attains a minimum figure at 43 degrees - 46 degrees in these two soils. The side force on the disk per inch of width cut decreases as the disk angle is increased. The projection of the disk in a plane parallel to the line of travel decreases as the disk angle increases, thus making it logical to expect the side force to diminish as indicated in the table. The data in Table 2 were used for plotting the curves in Fig. 3. Included in this table are a few figures for the 4-1/8-inch concavity disk in the Decatur Clay. Not only are the unit draft and the side pressures on the disk much higher than was observed for the Norfolk Sand and Davidson Loam but the reaction of the soil on the disk is definitely upward at all the angles and of considerable size. Since the soil reactions on the disk are more or less complicated by a certain amount of soil sticking to the disk in the Decatur Clay, these figures are given primarily to show the magnitude of the soil reactions rather than definite trends.

Table 3 shows a comparison of the soil reaction on the disk with the 4-1/8-inch concavity under different soil conditions. There is not a significant difference in the vertical reaction on the disk but in the dryer soil the unit draft is consistently higher. The side component of the soil reaction is also higher in the dryer soil, except at the extreme angle of 51 degrees where the figure is practically the same in both instances.

TABLE 3

Soil Reactions for Various Disk Angles Under Two Different Soil Conditions

Disk Angle	Unit Draft Lbs./Sq.In.	Total Vertical Force Downward Pounds	Side Force To Left Pounds	Power Requirements H.P. Hrs./Acre	Disk Concavity – 4-1/8" Radius of Curvature – 22-3/16" Depth of Cut – 4" Speed – 2.2 mph Width of Cut – corresponds with a disk spacing 10"		
36	3.94	28*	50	3.55	Soil Type – Davidson Loam Soil Conditions		
41	4.07	7	81	3.83	Depth	A.S.G.	Moist.%
46	4.51	6	80	4.40	0-2	1.66	11.98
51	4.68	20	72	4.65	2-4	1.72	11.08
36	5.80	16*	116	5.22			
41	5.34	22	107	5.02			
46	5.61	7*	94	5.48	0-2	1.61	6.70
51	6.30	14	74	6.27	2-4	1.77	8.65

* Indication that soil reaction is upward.

In the foregoing discussion the disk was held in a vertical position. By tipping the disk back at some angle with the vertical, the soil reactions on the disk follow a slightly different trend.

For similar soil conditions it has been observed that the unit draft was increased to some extent when the disk is tipped as compared with the unit draft when the disk is held vertical. The ability of the disk to penetrate is generally improved although from observations in the Norfolk Sand and Davidson Loam, this does not always hold true. When the disk is tipped back, the side force is considerably reduced. In Table 4 the soil reactions on a 26-inch disk with a 4-1/8-inch concavity are shown, which bring out the points discussed above.

Table 5 and Fig. 4 show the effect of a 5-degree change in disk angle on the various components of soil reaction.

For disks of the same concavity the setting for disk angle is limited to a greater extent when inclined than when held in a vertical position. The convex side of the disk is closer to the soil and by a slight change in disk angle can be brought to bear on the soil. Any appreciable bearing of the convex side of the disk would be reflected in the vertical force reading. In this instance, the disk with the 4-3/8-inch concavity has a high upward reaction at 46 degrees. With an increase of 5 degrees in the disk angle to 51 degrees, the vertical component of soil reaction changes so that it is downward in direction. The unit draft is considerably lower at the 51-degree disk angle also.

TABLE 4

Soil Reaction in Relation to Angle of Inclination

		Total				
Angle of Inclination Degrees	Unit Draft Lbs./Sq.In.	Vertical Force Downward Pounds	Side Force To Left Pounds	Disk Concavity - 4-1/8" R. of Curvature - 22-3/16" Disk Angle - 46° Speed - 3.6 mph Depth of Cut - 6" Width of Cut - 7"		
				Soil Type - Norfolk Sand		
25	3.00	34	27	Soil Conditions		
22	3.14	75	42	Depth	A.S.G.	Moist.%
18	2.88	69	50	0-2	1.74	3.62
0	2.83	57	69	2-4	1.78	5.76
				4-6	1.73	7.57
				Soil Type - Davidson Loam		
25	6.22	28	59	Soil Conditions		
22	6.44	12	64	Depth	A.S.G.	Moist.%
18	5.56	15	47	0-2	1.53	7.24
0	5.30	32	125	2-4	1.70	9.25
				4-6	1.72	10.82

TABLE 5

Soil Reaction in Relation to Angle of Inclination at Two Different Disk Angles

			Total		
Angle of Inclination Degrees	Disk Angle	Unit Draft Lbs./Sq.In.	Vertical Force Downward Pounds	Side Force To Left Pounds	Disk Concavity - 4-1/8" R. of Curvature - 22-3/16" Width of Cut - 7" Depth of Cut - 8" Speed - 3.6 mph
					Soil Type - Davidson Loam
25	46	5.97	16	30	Soil Conditions
22	46	6.75	35	92	Depth A.S.G. Moist.%
17.5	46	6.45	98	112	0-2 1.66 10.64
0	46	5.16	16	94	2-4 1.80 9.42
					4-6 1.66 9.62
					6-8 1.70 10.81
25	51	5.59	29	38	
22	51	5.65	26	49	
17.5	51	5.40	53	63	
0	51	5.49	37	130	
	(Note: Above data plotted in Fig. 4)				
					Soil Type - Davidson Loam
					Soil Conditions
25	46	8.15	214*	62[1]	Depth A.S.G. Moist.%
22	46	8.37	25*	9	0-2 1.85 9.7
18	46	7.86	34*	27	2-4 1.79 10.5
					4-6 1.66 10.5
25	51	7.19	55	46	Disk Concavity - 4-3/8"
22	51	7.00	66	61	R. of Curvature - 21-1/4"
18	51	7.29	0	55	Depth of Cut - 6"
					Width of Cut - 9"

* Vertical component of soil reaction is upward.

[1] Side component of soil reaction is to the right.

That portion of the table showing the soil reactions on the disk with 4-1/8-inch concavity does not indicate any great differences in the vertical reactions at either the 46 or 51-degree disk angles. The unit draft, however, is lower at the 51-degree disk angle. It should be noted that the unit draft is lowest with the disk held vertical and at a disk angle of 46 degrees. The data for the disks of two different concavities brings out the effect of small changes of angle, especially on the deeper concavity disks.

Effect of Speed on Soil Reactions on Disks

Fig. 5 and Table 6 show the effect of speed of operation in two different soils, the Norfolk Sand and the Davidson Loam plots. The draft per square inch of soil cross section more than doubles when the speed is stepped up from 2-1/2 miles per hour to 5 miles per hour in the Davidson Loam Soil. The side reaction on the disk follows the trend of the draft. This increase in soil reaction on the disk is apparently due to the fact that more work is being done in casting the soil farther forward and to the side at the higher speed as compared with what takes place at the lower speeds. There is also a greater amount of pulverization taking place.

The reaction of the soil is downward on the disk in both soils with the soil conditions as shown, but this reaction downward tends to lessen at the higher speeds. For the Davidson Loam Soil the reduction in downward reaction on the disk is considerable, in this case amounting to about 70% between 2-1/2 and 5 miles per hour. The difference in the downward reaction on the disk in the Norfolk Sand

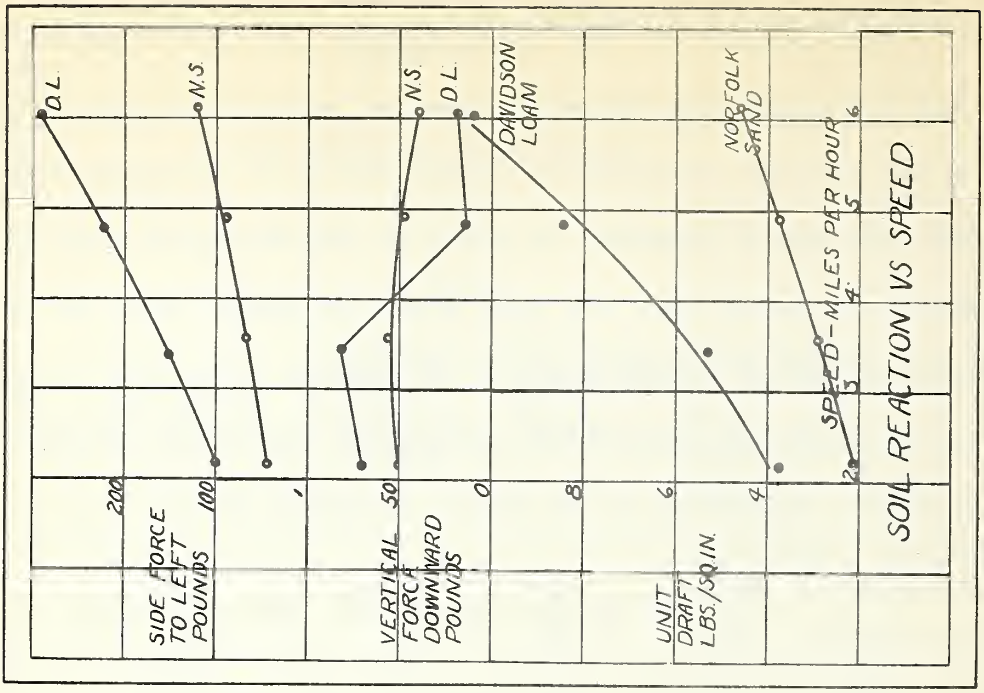

Fig. 5

Soil Reaction on Vertical Disks in Relation to Speed.
(Data plotted from Table 6)

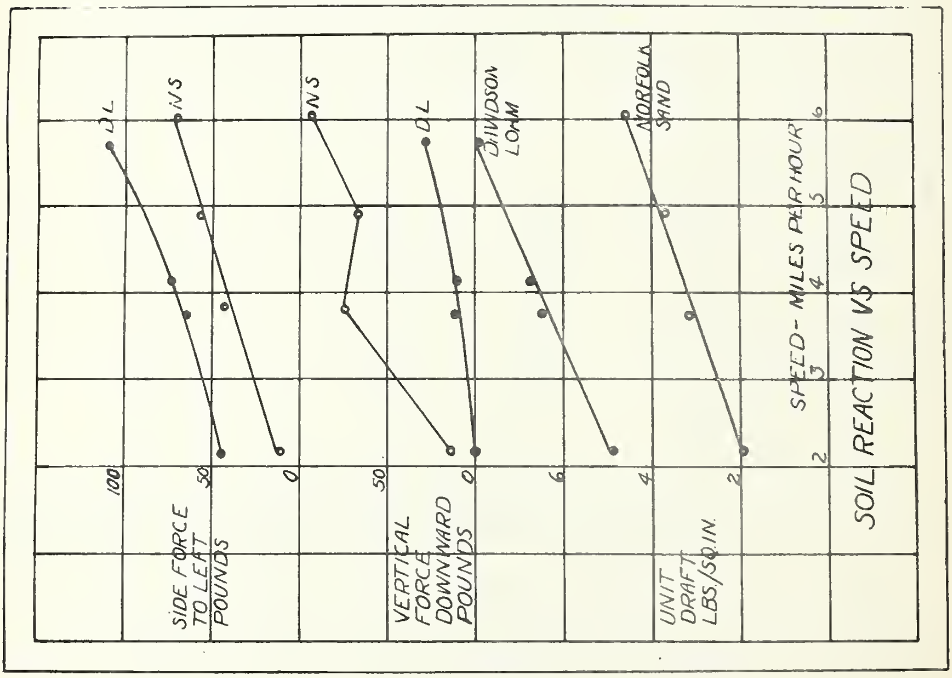

Fig. 6

Soil Reaction on Inclined Disks in Relation to Speed.
(Data plotted from Table 7)

TABLE 6

Effect of Speed on Soil Reactions on Vertical Disks

		Total			Disk Concavity – 4-1/8", R. of Curvature – 22-3/16"		
Speed mph	Unit Draft Lbs./Sq.In.	Vertical Force Downward Pounds	Side Force To Left Pounds	H.P. Hrs./Acre	Disk Angle-46°, Width of Cut-7", Depth of Cut-6".		
					Soil Type – Norfolk Sand		
					Soil Conditions		
2.28	2.09	51	45	3.11	Depth	A.S.G.	Moist.%
3.56	2.83	57	69	4.22	0-2	1.70	3.57
4.90	3.64	43	89	5.42	2-4	1.76	5.46
6.13	4.55	43	124	6.78	4-6	1.73	7.34
					Soil Type – Davidson Loam %		
					Soil Conditions		
2.18	3.68	71	100	5.52	Depth	A.S.G.	Moist.
3.41	5.26	83	153	7.89	0-2	1.67	8.58
4.81	8.48	15	223	12.72	2-4	1.92	11.14
6.03	10.40	20	295	15.57	4-6	1.87	12.46

at the high and low speed is not enough to affect the depth of penetration but in the Davidson Loam the reduction is quite appreciable.

That portion of the soil reaction acting horizontally to the left on the disk averages about 60 - 70% of the draft in the Davidson Loam.

With the disk blade inclined at some angle with the vertical, the soil reactions change materially, especially in the Davidson Loam. However, a comparison on the draft for the Norfolk Sand with the disk held vertical as against the draft with the disk tipped back at 22 degrees with the vertical shows that it is practically identical throughout the range of speeds studied. With the disk inclined, the vertical reaction downward increases as the speed is increased, whereas in the vertical position the downward reaction decreases as the speed increases. The horizontal reaction to the left on the disk tipped at 22 degrees is considerably less than the reaction on the disk held in the vertical position.

In the Davidson Loam, the vertical reaction downward on the disk increases as the speed increases with the disk tipped at 22 degrees with the vertical. In this soil the horizontal side component is reduced greatly with the disk inclined 22 degrees as compared with the figure for this component with the disk in the vertical position (compare Table 6 and Table 7). The reduction in the horizontal side component with the disk tipped back is probably due to the fact that there is a comparatively smooth flow of the soil over the disk blade whereas with the blade in the vertical position, the furrow slice is met more abruptly, and a greater acceleration to the right is given to the soil

TABLE 7

Effect of Speed on Soil Reactions on Inclined Disks

		Total				
Speed mph	Unit Draft Lbs./Sq.In.	Vertical Force Downward Pounds	Side Force To Left Pounds	Angle of Inclination - 22° Width of Cut - 7" Depth of Cut - 6" Disk Angle - 46° Disk Concavity - 4-1/8" R. of Curvature - 22-3/16"		
				Soil Type - Norfolk Sand		
2.15	1.93	14	11	Soil Conditions		
3.81	3.14	75	42	Depth	A.S.G.	Moist.%
4.90	3.64	66	56	0-2	1.76	3.59
6.03	4.55	94	70	2-4	1.79	6.07
				4-6	1.71	7.78
				Soil Type - Davidson Loam		
2.18	4.81	0	45	Soil Conditions		
3.73	6.44	12	64	Depth	A.S.G.	Moist.%
4.12	6.75	10	73	0-2	1.52	6.28
5.72	7.90	28	110	2-4	1.58	8.04
				4-6	1.62	9.32

particles.

In connection with these studies of the effect of speed, the unit draft of a disk has been observed to be about equal to that of a moldboard plow equipped with rolling colter and jointer under similar conditions of speed and soil.

Soil Reaction in Relation to Depth of Cut

Under adverse conditions usually the vertical disk plow or standard disk plow is set as deep as soil conditions will permit or as deep as possible with the power available. The trend of the soil reactions at various depths indicates that the disk blade handles the soil from the standpoint of draft at some depths better than others. Also, the vertical reactions are likely to be more desirable from the standpoint of smoother operation at certain depths as compared with others.

The unit draft per square inch of furrow slice cross section is a minimum at the 6-inch depth of cut in both the Norfolk Sand and the Davidson Loam. The vertical reaction downward and the side reaction to the left on the disk increases as the depth of cut is increased in the Norfolk Sand. The vertical reaction in the Davidson Loam changes from a small upward component at the 4-inch depth to a downward one at the 6 and 8-inch depth, being a maximum at the 6-inch depth.

TABLE 8

Soil Reactions in Relation to Depth of Cut

		Total					
Width of Cut Inches	Unit Draft Lbs./Sq.In.	Vertical Force Downward Pounds	Side Force To Left Pounds	Depth of Cut Inches	Disk Concavity - 4-1/8" R. of Curvature - 22-3/16" Disk Angle - 46° Speed - 2.2 mph		
					Soil Type - Norfolk Sand		
7.0	1.81	4	10	4	Soil Conditions		
7.0	1.36	32	47	6	Depth	A.S.G.	Moist.%
7.0	2.00	64	73	8	0-2	1.60	4.28
					2-4	1.76	6.50
					4-6	1.75	7.58
					6-8	1.69	8.48
					Soil Type - Davidson Loam		
7.0	5.61	7*	94	4	Soil Conditions		
7.0	4.99	31	103	6	Depth	A.S.G.	Moist.%
7.0	5.83	11	178	8	0-2	1.65	7.41
					2-4	1.77	9.22
					4-6	1.82	9.98
					6-8	1.83	11.73

* Indication that soil reaction is upward on disk.

Disk Concavity

Disk concavity or the distance from the disk center to the plane of the disk cutting edge is inversely proportional to the radius of curvature. The so-called cover-crop disk and plow disk has a comparatively small radius of curvature while the disk blades on a disk harrow unit are usually shaped with a longer radius of curvature.

The manner in which the soil reacts to disk blades having different concavities is shown in the following tabulation.

The fact that the side component acting at right angles to the line of travel is greater for shallow concavity disk holds for the Decatur Clay as well as the Davidson Loam. This appears logical if the angle of tangency of that portion of the two disk blades cutting the furrow slice is considered.

The Draft for the shallow concavity disk increases considerably at the 51° angle, due to the abrupt angle at which the disk cuts the furrow slice.

Bearing Friction

The observations discussed in this paper were made with the disk mounted on a spindle which rotates in an anti-friction bearing. A few tests were made in the heavy clay soils in which the disk was locked so that it could not turn. These tests showed a higher draft than was observed where the disk was free to turn. The vertical reaction on the disk indicated that less weight is required for penetration when the disk cannot rotate. The horizontal component of soil reaction was reduced with the disk not rotating.

TABLE 9

Soil Reactions at Different Disk Angles on Disks of Different Concavities

Disk Concavity Inches	Radius of Curvature Inches	Disk Angle	Unit Draft Lbs./Sq.In.	Total Vertical Force Downward Pounds	Total Side Pressure To Left Pounds	Test Conditions Speed - 3.6 mph Width of Cut - 7" Depth of Cut - 6"		
						Soil Type - Davidson Loam		
						Soil Conditions		
2-15/16	30	41	6.41	10	245	Depth	A.S.G.	Moist.%
4-15/16	18-1/8	41	7.25	160*	40[1]	0-2	1.81	8.49
						2-4	1.88	10.16
						4-6	1.80	11.38
2-15/16	30	46	5.62	37	191			
4-15/16	18-1/8	46	7.16	70	174			
2-15/16	30	51	7.67	18	229			
4-15/16	18-1/8	51	6.61	62	156			
						Soil Type - Decatur Clay		
						Soil Conditions		
						Depth	A.S.G.	Moist.%
2-15/16	30	46	10.45	168*	332	0-2	1.56	12.3
4-15/16	18-1/8	46	11.3	172*	283	2-4	1.50	16.1
						4-6	1.56	18.4
						Depth of Cut - 6"		
						Speed - 3.6 mph		

* Indicates that soil reaction is upward.

[1] Indicates that side force is to the right.

Soil Reaction in Relation to Disk Diameter

The question is often asked about the comparative performance of disks of different diameters. The data for two disks having approximately the same radius of curvature are shown in the following table. The diameters are 26 inches and 20 inches, respectively.

The depth and width of cut are the same for both disks. At the disk angles studied, there was no appreciable difference in the vertical component of the soil reaction. At the 46-degree disk angle, the penetration factor was improved somewhat for the larger diameter disk. The side component of the soil reaction is lower for the 26-inch disk. In a similar series of tests in which the depth was increased one inch, the increased side thrust on the smaller disk was still more pronounced.

A Comparison of Soil Reactions on Two Different Disk Diameters

			Total	
Disk Diameter	Disk Angle	Unit Draft Lbs./Sq.In.	Vertical Force Downward Pounds	Side Force To Left Pounds
20	36	5.73	38*	121
20	41	5.18	22*	124
20	46	5.70	21*	129
26	36	5.45	37*	93
26	41	5.19	19*	102
26	46	6.12	10	117

Depth of Cut - 5"
Width of Cut - 7"
26" disk - 22-1/4" R. of curvature.
20" disk - 23-3/8" R. of curvature.

Soil Type - Davidson Loam.

Soil Conditions

Depth	A.S.G.	Moist.%
0-2	1.62	9.94
2-4	1.61	9.44
4-6	1.63	9.85

* Indication that vertical reaction is upward.

Disk Scrapers

Except where noted, the tests were made without scrapers. A limited number of runs have been made, observing the use of scrapers on disks of smaller diameter than 26 inches in clay soils. It was found that with the scrapers, the draft and the side reactions were materially reduced and the ability of the disk to penetrate was improved considerably.

Disk Rotation

The test unit was equipped to record the rotation of the disk blade as it was pulled through the soil. This rotation is caused by the reaction of the soil on the disk and the fact that it changes for various test conditions indicates that the summation of forces tending to make it turn are definitely influenced by the manner in which the furrow slice is sheared and moved over the disk blade.

Disk rotation is increased as the speed of travel is increased.

Speed Miles per hour	Ratio of Disk Rotation to Ground Travel	Soil Type - Davidson Loam Disk Concavity - 4-1/8" Disk Angle - 41°
2.45	.95	
3.63	.98	
4.72	1.06	
5.99	1.09	

If the convex side of the disk bears on the soil the effect on the disk is to slow it down. A slight change of disk angle which causes the side component of the soil reaction to change direction so that it is acting toward the concave side of the disk makes the disk rotate considerably faster and as the disk angle is further increased, the rotation decreases.

Disk Rotation in Relation to Disk Angle

Disk Angle Degrees	Ratio of Disk Rotation to Ground Travel	Soil Type - Davidson Loam Disk Concavity - 4-3/8" Depth of Cut - 6" Speed - 3.6 mph Width of Cut corresponds to Disk Spacing of 10"
36	0.84*	
41	1.04	
46	0.95	
51	0.88	

* Side component of soil reaction acting to the right on the disk.

With the disk angle set for average operating conditions, the disk rotation increases as the width of cut increases.

Width of Cut	Ratio of Disk Rotation to Ground Travel	Soil Type - Davidson Loam Disk Concavity - 4-3/8" Disk Angle - 46° Depth of Cut - 6"
5.6	.89	
7.0	.95	
8.3	.99	

The relationship between disk rotation and depth of cut was not definitely established. At the narrow widths of cut there does not appear to be any significant differences in disk rotation for the three depths studied, 4, 6, and 8 inches. At an 8 or 9-inch width of cut, disk rotation is increased noticeably at the 8-inch depth.

When the disk is inclined back from the vertical position rotation is slowed down considerably.

Angle of Inclination with the Vertical Degrees	Ratio of Disk Rotation to Ground Travel	Soil Type - Norfolk Sand Speed - 3.6 mph Disk Concavity - 4-1/8" Disk Angle - 46° Width of Cut - 7" Depth of Cut - 6"
25	0.69	
18	0.76	
0	0.84	
2*	0.86	

* Tipped forward

Disk rotation increases as the depth of concavity of the disk is increased.

Concavity Inches	Ratio of Disk Rotation To Ground Travel	Soil Type - Davidson Loam Speed - 3.6 mph Disk Angle - 46° Width of Cut - 7" Depth of Cut - 6"
2-15/16	0.99	
4-1/8	1.04	
4-3/8	1.09	
4-15/16	1.15	

Due to the complexity of the resultant soil reactions on the disk, there does not appear to be any definite relationship between soil reaction and disk rotation. Mention has been made under a discussion of bearing friction that with the disk free to turn the draft is less and disk penetration is decreased as against conditions prevailing when the disk locked from turning. Then the draft increases and disk penetration is improved.

The tests discussed herein are to be considered more or less exploratory and were made in order to determine the trend of soil reactions on disks under certain conditions. To fully evaluate each factor would involve a much greater number of tests than are indicated in this report.

SUMMARY

1. The factor of soil type and soil conditions within a given soil type have been found to have perhaps the greatest effect on the magnitude of soil reactions on the disk. In average soil conditions the draft of a disk blade cutting 6 inches deep and 7 inches wide will vary from about 75 pounds per disk in the Norfolk Sand to five or six times that much in the Decatur Clay. The vertical reaction will change from a downward component of about 60 pounds in the Norfolk Sand to an upward component of 170 pounds in the Decatur Clay. Under average operating conditions the side component of the soil reaction on a disk blade of 4-1/8-inch concavity is roughly 50-70% of the draft on the disk.

2. The factor of speed exerts a definite influence on the soil reactions on the disk. With the disk held in a vertical position, the draft is doubled by increasing the speed from 2-1/2 to 5 miles per hour in the Davidson Loam. The horizontal component at right angles to the line of travel increases at about the same rate as the draft. With the disk held in a vertical position, the penetration tends to decrease with an increase in speed.

3. With the disk tipped back the penetration tends to increase with the speed. The draft does not increase as fast with the disk inclined.

4. Comparing the draft of the disk with that of a moldboard plow, it has been observed that the unit draft of a disk is about the same as that for a moldboard plow equipped with a rolling colter and jointer.

5. Studies of the soil reaction for various disk angles and angles of inclination were made. The unit draft reaches a minimum in the Davidson Loam and Norfolk Sand at disk angles between 40 and 45 degrees. The ability of the disk to penetrate increased with disk angles up to around 45 degrees. The side component of the soil reaction becomes less as the disk angle is increased.

6. As the disk is tipped back, the unit draft increases to a certain extent, the side force becomes less and usually the penetration factor is improved for angles of inclination around 18 to 22 degrees.

7. A disk with short radius of curvature or deep concavity will penetrate better than a shallow concavity disk. However, the disk with a shallow concavity will operate over a wider range of disk angle settings. The side component of the soil reaction is greater with the shallow concavity disks.

8. The freedom with which the disk rotates on its bearings influences the manner in which the soil reacts on the disk.

9. If the soil is inclined to stick to the disk blade, the removal of the soil with scrapers materially reduced the magnitude of the soil reactions.

10. The unit draft and penetration of disks of different diameters cutting the same depth and width does not differ materially. The

side component of the soil reaction is higher for the smaller diameter disk since it is cutting a proportionately deeper furrow for its diameter and the soil must be lifted slightly higher.

11. Disk rotation is influenced by the direction and magnitude of the resulting soil reactions on the disk as evidenced by the manner in which changes of disk angle, speed, angle of inclination, disk concavity, width and depth of cut change the amount of disk rotation.